CLAIMS

1. A method of controlling a switching regulator to supply a regulated output voltage at an output node, switching regulator comprising an inductor having first and second terminals, a first switch coupled between an input voltage and the first terminal of the inductor, a second switch coupled between the first terminal of the inductor and a first reference voltage, a third switch coupled between the second terminal of the inductor and the output node, and a fourth switch coupled between the second terminal of the inductor and a second reference voltage, the method comprising:

generating a feedback signal proportional to the regulated output voltage of switching regulator;

generating first, second, third and fourth control signals to control the first, second, third, and fourth switches, respectively, in response to the feedback signal and to provide a first state in which the first and third switches are closed and the second and fourth switches are open, a second state in which the second and third switches are closed and the first and fourth switches are open, and a third state in which the first and fourth switches are closed and the second and third switches are open; and

adjusting, in a first mode of operation, a number of state transitions from the first state to the second state relative to a number of state transitions from the first state to the third state in response to the feedback signal.

2. The method of Claim 1, wherein said adjusting step comprises generating a digital waveform having a pulse rate proportional to the feedback signal.

3. The method of Claim 2, wherein the generating the digital waveform comprises generating the digital waveform with a sigma-delta converter.

4. The method of Claim 2, wherein said adjusting step further comprises:

generating the first, second, third and fourth control signals to provide transitions between the first state and the second state during a first state of the digital waveform; and

generating the first, second, third and fourth control signals to provide transitions between the first state and the third state during a second state of the digital waveform.

5. The method of Claim 2, wherein said adjusting step further comprises:

generating a periodic analog waveform having a predetermined amplitude;

comparing the periodic analog waveform with a first fixed voltage to provide a first comparison signal;

comparing the periodic analog waveform with a second fixed voltage to provide a second comparison signal; and

logically combining the first comparison signal, the second comparison signal, and the digital waveform to provide the first, second, and third states.

6. The method of Claim 5, wherein the periodic analog waveform includes a selected one of a periodic sawtooth waveform and a periodic triangle waveform.

7. The method of Claim 1, wherein said generating the first, second, third and fourth control signals further provides a fourth state in which the second and fourth switches are closed and the first and third switches are open in response to an error condition.

8. The method of Claim 1, wherein switching regulator is adapted to operate with the input voltage substantially equal to the regulated output voltage in the first mode of operation.

9. The method of Claim 1, further comprising adjusting a duration in the first state relative to a duration in the second state in response to the feedback signal in a second mode of operation in which the input voltage is higher than the regulated output voltage.

10. The method of Claim 9, further comprising adjusting a duration in the first state relative to a duration in the third state in response to the feedback signal in a third mode of operation in which the input voltage is lower than the regulated output voltage.

11. The method of Claim 1, wherein at least one of the second and third switches is a diode.

12. A method of controlling a switching regulator to supply a regulated output voltage at an output node, switching regulator comprising an inductor having first and second terminals, a first switch coupled between an input voltage and the first terminal of the inductor, a second

switch coupled between the first terminal of the inductor and a first reference voltage, a third switch coupled between the second terminal of the inductor and the output node, and a fourth switch coupled between the second terminal of the inductor and a second reference voltage, the method comprising:

generating a feedback signal proportional to the regulated output voltage of switching regulator;

generating a periodic analog waveform; and

generating first, second, third and fourth control signals to control the first, second, third, and fourth switches, respectively, in response to the feedback signal and to provide a first state in which the first and third switches are closed and the second and fourth switches are open, a second state in which the second and third switches are closed and the first and fourth switches are open, and a third state in which the first and fourth switches are closed and the second and third switches are open, wherein, in a first mode of operation, a duty cycle of the first state within all periods of the periodic analog waveform corresponds to a first predetermined value, a duty cycle of the second state within periods of the periodic analog waveform in which the second state occurs corresponds to a second predetermined value, and a duty cycle of the third state within periods of the periodic analog waveform in which the third state occurs corresponds to a third predetermined value.

13. The method of Claim 12, wherein the first predetermined value is in the range of fifty five percent to ninety-eight percent, and the second and third predetermined values are in the range of two percent to forty-five percent.

14. The method of Claim 12, wherein said generating the first, second, third and fourth control signals comprises generating a digital waveform having a pulse rate proportional to the feedback signal.

15. The method of Claim 14, wherein the generating the digital waveform comprises generating the digital waveform with a sigma-delta converter.

16. The method of Claim 14, wherein said generating the first, second, third and fourth control signals further comprises:

generating the first, second, third and fourth control signals to provide transitions between the first state and the second state during a first state of the digital waveform; and

generating the first, second, third and fourth control signals to provide transitions between the first state and the third state during a second state of the digital waveform.

17. The method of Claim 14, wherein said generating the first, second, third and fourth control signals further comprises:

generating the periodic analog waveform having a predetermined amplitude;

comparing the periodic analog waveform with a first fixed voltage to provide a first comparison signal;

comparing the periodic analog waveform with a second fixed voltage to provide a second comparison signal; and

logically combining the first comparison signal, the second comparison signal, and the digital waveform to provide the first, second, and third states.

18. The method of Claim 17, wherein the periodic analog waveform includes a selected one of a periodic sawtooth waveform and a periodic triangle waveform.

19. The method of Claim 12, wherein said generating the first, second, third and fourth control signals further provides a fourth state in which the second and fourth switches are closed and the first and third switches are open in response to an error condition.

20. The method of Claim 12, wherein switching regulator is adapted to operate with the input voltage substantially equal to the regulated output voltage in the first mode of operation.

21. The method of Claim 12, further comprising adjusting a duration in the first state relative to a duration in the second state in response to the feedback signal in a second mode of operation in which the input voltage is higher than the regulated output voltage.

22. The method of Claim 21, further comprising adjusting a duration in the first state relative to a duration in the third state in response to the feedback signal in a third mode of operation in which the input voltage is lower than the regulated output voltage.

23. The method of Claim 12, wherein at least one of the second and third switches is a diode.

24. A method of controlling a switching regulator to supply a regulated output voltage at an output node, switching regulator comprising an inductor having first and second terminals, a first switch coupled between an input voltage and the first terminal of the inductor, a second switch coupled between the first terminal of the inductor and a first reference voltage, a third switch coupled between the second terminal of the inductor and the output node, and a fourth switch coupled between the second terminal of the inductor and a second reference voltage, the method comprising:

generating a feedback signal proportional to the regulated output voltage of switching regulator;

generating a periodic analog waveform;

generating first, second, third and fourth control signals to control the first, second, third, and fourth switches, respectively, in response to the feedback signal and to provide a first state in which the first and third switches are closed and the second and fourth switches are open, a second state in which the second and third switches are closed and the first and fourth switches are open, and a third state in which the first and fourth switches are closed and the second and third switches are open, wherein, in a first mode of operation, state transitions consist of a transition from the first state to the second state and a transition from the second state to the first state in a first period of the periodic analog waveform and from the first state to the third state and from the third state to the first state in a second period of the periodic analog waveform.

25. The method of Claim 24, wherein said generating the first, second, third and fourth control signals comprises generating a digital waveform having a pulse rate proportional to the feedback signal.

26. The method of Claim 25, wherein the generating the digital waveform comprises generating the digital waveform with a sigma-delta converter.

27. The method of Claim 25, wherein said generating the first, second, third and fourth control signals further comprises:

generating the first, second, third and fourth control signals to provide transitions between the first state and the second state during a first state of the digital waveform; and

generating the first, second, third and fourth control signals to provide transitions between the first state and the third state during a second state of the digital waveform.

28. The method of Claim 25, wherein said generating the first, second, third and fourth control signals further comprises:

generating the periodic analog waveform having a predetermined amplitude;

comparing the periodic analog waveform with a first fixed voltage to provide a first comparison signal;

comparing the periodic analog waveform with a second fixed voltage to provide a second comparison signal; and

logically combining the first comparison signal, the second comparison signal, and the digital waveform to provide the first, second, and third states.

29. The method of Claim 28, wherein the periodic analog waveform includes a selected one of a periodic sawtooth waveform and a periodic triangle waveform.

30. The method of Claim 24, wherein said generating the first, second, third and fourth control signals further provides a fourth state in which the second and fourth switches are closed and the first and third switches are open in response to an error condition.

31. The method of Claim 24, wherein switching regulator is adapted to operate with the input voltage substantially equal to the regulated output voltage in the first mode of operation.

32. The method of Claim 24, further comprising adjusting a duration in the first state relative to a duration in the second state in response to the feedback signal in a second mode of operation in which the input voltage is higher than the regulated output voltage.

33. The method of Claim 32, further comprising adjusting a duration in the first state relative to a duration in the third state in response to the feedback signal in a third mode of operation in which the input voltage is lower than the regulated output voltage.

34. The method of Claim 24, wherein at least one of the second and third switches is a diode.

35. A control circuit for controlling a switching regulator to supply a regulated output voltage at an output node, switching regulator comprising an inductor having first and second terminals, a first switch coupled between an input voltage and the first terminal of the inductor, a second switch coupled between the first terminal of the inductor and a first reference voltage, a third switch coupled between the second terminal of the inductor and the output node, and a fourth switch coupled between the second terminal of the inductor and a second reference voltage, the control circuit comprising:

a feedback amplifier for generating a feedback signal proportional to the regulated output voltage of switching regulator;

a digital waveform generator responsive to the feedback signal for providing a digital waveform having a pulse rate proportional to the feedback signal;

an analog waveform generator for generating a periodic analog waveform having a predetermined amplitude;

at least one comparator for comparing the periodic analog waveform to at least one fixed voltage and for providing a respective at least one comparison output signal; and

logic circuitry responsive to the at least one comparison output signal, and having first, second, third, and fourth control outputs coupled to the first, second, third, and fourth switches respectively, for providing a first state in which the first and third switches are closed and the second and fourth switches are open, a second state in which the second and third switches are closed and the first and fourth switches are open, and a third state in which the first and fourth switches are closed and the second and third switches are open, wherein, in a first mode of operation, said logic circuitry is adapted to adjust a number of state transitions from the first state to the second state relative to a number of state transitions from the first state to the third state in response to the feedback signal.

36. The control circuit of Claim 35, further including at least one other comparator for comparing the feedback signal to the periodic analog waveform to provide at least one other comparison output signal, and wherein the logic circuitry is further responsive to the at least one other comparison signal.

37. The control circuit of Claim 35, wherein the first, second, third and fourth control signals provide transitions between the first state and the second state during a first state of the digital waveform, and the first, second, third and fourth control signals provide transitions between the first state and the third state during a second state of the digital waveform.

38. The control circuit of Claim 35, wherein the digital waveform generator comprises a sigma-delta converter.

39. The control circuit of Claim 35, wherein the periodic analog waveform includes a selected one of a periodic sawtooth waveform and a periodic triangle waveform.

40. The control circuit of Claim 35, wherein the logic circuitry further provides a fourth state in which the second and fourth switches are closed and the first and third switches are open in response to an error condition.

41. The control circuit of Claim 35, wherein switching regulator is adapted to operate with the input voltage substantially equal to the regulated output voltage in the first mode of operation.

42. The control circuit of Claim 35, wherein the logic circuitry is further adapted to adjust a duration in the first state relative to a duration in the second state in response to the feedback signal in a second mode of operation in which the input voltage higher is than the regulated output voltage.

43. The control circuit of Claim 42, wherein the logic circuitry is further adapted to adjust a duration in the first state relative to a duration in the third state in response to the feedback

signal in a third mode of operation in which the input voltage is lower than the regulated output voltage.

44. The control circuit of Claim 35, wherein at least one of the second and third switches is a diode.

45. A method of controlling a switching regulator to supply a regulated output voltage at an output node, switching regulator comprising an inductor having first and second terminals, a first switch coupled between an input voltage and the first terminal of the inductor, a second switch coupled between the first terminal of the inductor and a first reference voltage, a third switch coupled between the second terminal of the inductor and the output node, and a fourth switch coupled between the second terminal of the inductor and a second reference voltage, the method comprising:

generating a feedback signal proportional to the regulated output voltage of switching regulator;

generating a periodic analog waveform; and

generating first, second, third and fourth control signals to control the first, second, third, and fourth switches, respectively, in response to the feedback signal and to provide a first state in which the first and third switches are closed and the second and fourth switches are open, a second state in which the second and third switches are closed and the first and fourth switches are open, and a third state in which the first and fourth switches are closed and the second and third switches are open, wherein, during a single period of the periodic analog waveform, switches are in a selected two of the first, second, and third states.

46. The method of Claim 45, wherein a number of state transitions from the first state to the second state are adjusted relative to a number of state transitions from the first state to the third state in response to the feedback signal.

47. The method of Claim 45, wherein a duty cycle of the first state within all periods of the periodic analog waveform corresponds to a first predetermined value, a duty cycle of the second state within periods of the periodic analog waveform in which the second state occurs corresponds to a second predetermined value, and a duty cycle of the third state within periods

of the periodic analog waveform in which the third state occurs corresponds to a third predetermined value.

48. The method of Claim 45, wherein state transitions consist of a transition from the first state to the second state and a transition from the second state to the first state in a first period of the periodic analog waveform and from the first state to the third state and from the third state to the first state in a second period of the periodic analog waveform.